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Lead Containers in the Danish AEC Packagings for Radioactive Material

by

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Research Establishment Risö
Isotope Laboratory

Abstract

Three types of lead containers are at present used in the Danish AEC packagings for radioactive material: open type (5 and 10 mm), semi-closed type (20 and 30 mm) and closed type (45, 60, 80, and 100 mm). The open-type containers are used in tin cans as containment vessels in cardboard packagings. The others are used in the wooden packagings. The closed-type lead containers can be made leaktight and then used as containment vessels. Suitable methods for that purpose that have been tested and proved satisfactory are described. Radiation-shielding properties of the lead containers are discussed and a description of the evaluation of those properties given. Equipment and procedure for radiation leakage testing by the autoradiographic and radiometric method are described, and the test findings are discussed. Conclusions are drawn regarding the future use of all types of lead containers, and suggestions are made for extension of the open-type series, discutinuation of the use of the semi-closed series and extension of the closed-type series after it has been made leaktight.

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Contents

1. Introduction

In the Danish AEC packagings for the transport of radioactive material lead containers are used to reduce the dose rate of radiation to the presribed limits.

The lead containers constitute one of the several parts of which the transport packaging is constructed. The other parts of the transport packagings such as containment vessels and cardboard or wooden boxes have been described in previous reports[1,2,3].

In those reports it is mentioned that in the cardboard-type packagings the 5-, 10-, and 32-mm lead containers are used, and in the wooden-type packagings the 20-, 30-, 45-, 60-, 80-, and 100-mm containers.

All the above-mentioned lead containers together with other components such as the tin cans and cardboard and wooden boxes are shown in fig. 1, from which the components making up the eighteen types of the AEC packagings can be seen.

Lead containers used in those eighteen types of packagings can be divided into three groups:

- open-type containers (closed with adhesive tape),
- semi-closed-type containers (closed with two toggle fasteners),
- closed-type containers (closed with a lead plug).

All the lead containers have an internal cavity of the same dimensions, i.e. a diameter of 30 mm and a height of 73 mm.

2. Open-Type Containers

The 5- and 10-mm open lead containers are shown in fig. 2, and fig. 3 shows the 32-mm container. The basic dimensions of containers shown in fig. 2 are given in table 1.

Till now only the 5- and 10-mm open containers have been used, but as the result of the testing performed on the AEC packagings it was decided to use also the 20- and 30-mm open containers.

The 20-mm open container can be used inside the tin can making up the containment vessel (see 1)), whereas the 30-mm open container can be used for the transportation of sealed radioactive sources, where the source capsule may be regarded as the containment vessel. It is proposed to use the 30-mm open container in a new design of a foamed polystyrene packaging.

All the above-mentioned containers are closed with a 25-mm wide adhesive tape.

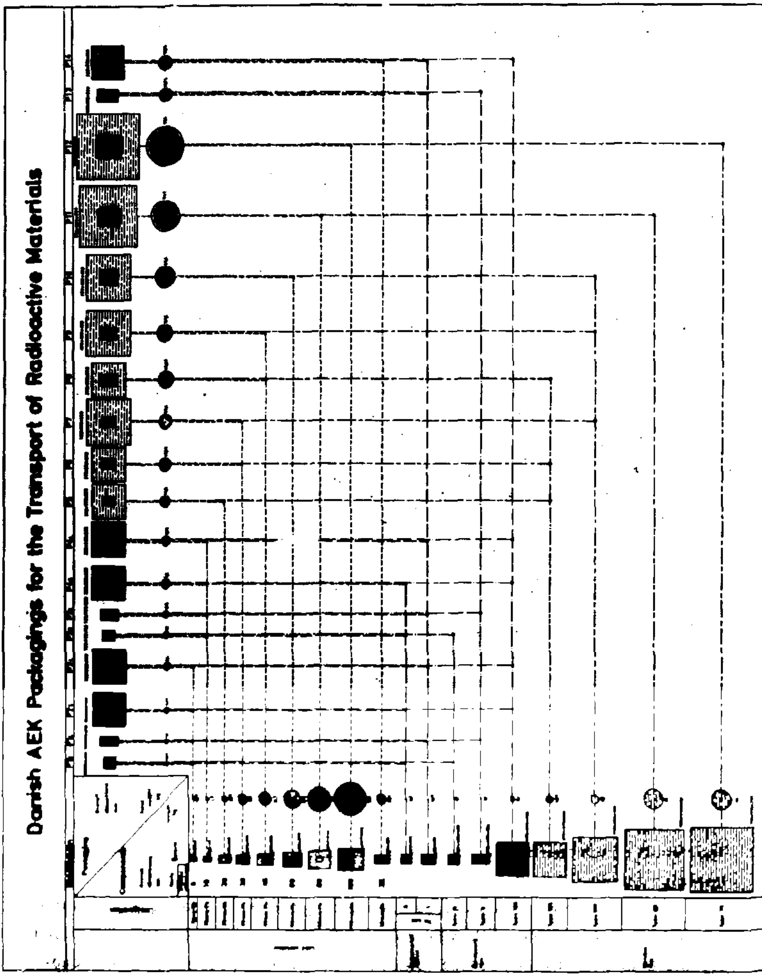

Fig. 1. Danish AEK packagings for the transport of radioactive materials.

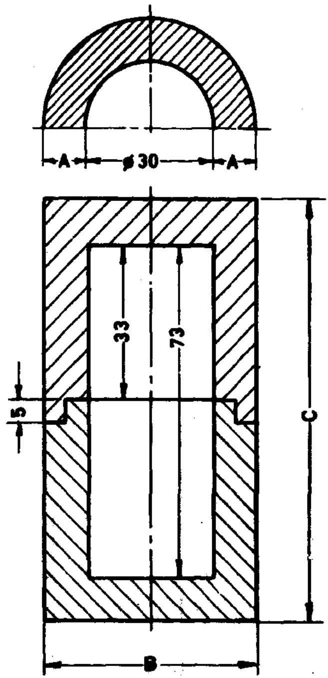

Fig. 2. Open-type lead container.

Table 1

Basic dimensions of the open-type lead containers

Wall thickness mm	A mm	B mm	C mm
5	5	40	83
10	10	50	93
20	20	70	113
30	30	90	133

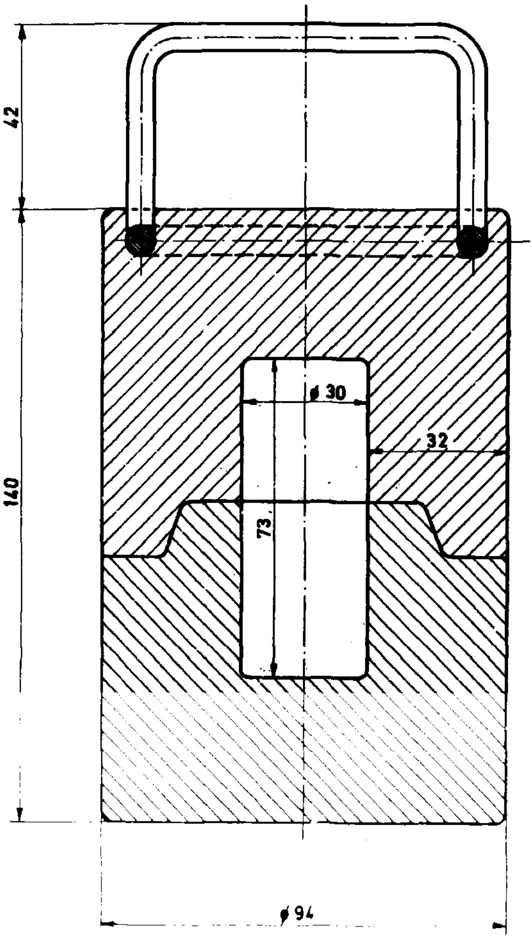

Fig. 3. 32-mm open-type lead container.

3. Semi-closed-Type Containers

The semi-closed containers are shown in fig. 4, and their basic dimensions are given in table 2. The containers were designed with 20- and 30-mm thick walls.

Table 2

Basic dimensions of the semi-closed-type lead containers

Wall thickness mm	A mm	B mm	C mm	D mm
20	20	70	76	124
30	30	90	97	145

These containers are closed with two toggle fasteners, as shown in fig. 4. The fasteners are designed to hold together the two parts of the container, but cannot ensure leaktightness, and therefore the semi-closed containers are not meant for use in cases where leaktightness must be ensured by the lead container itself.

4. Closed-Type Containers

For the lead thicknesses of 45 mm and above a third type of lead container is used. This is shown in fig. 5, and the basic dimensions of the containers are given in table 3.

The lead shield of these containers is composed of three parts: the lower and upper parts of the container and its plug. All those three parts are made of lead ensheathed in stainless steel. The upper and lower parts of the container are fastened together with two or six steel screws, which are covered by the top steel plate. This plate also serves to hold the plug in its closed position.

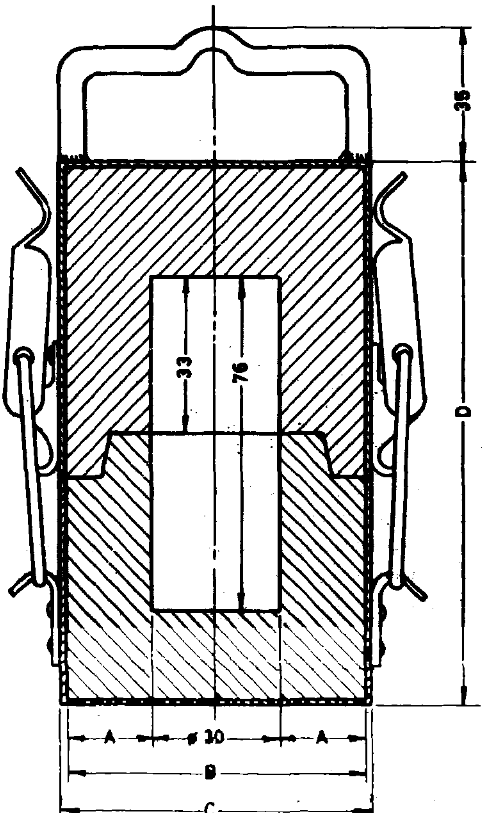

Fig. 4. Semi-closed-type lead container.

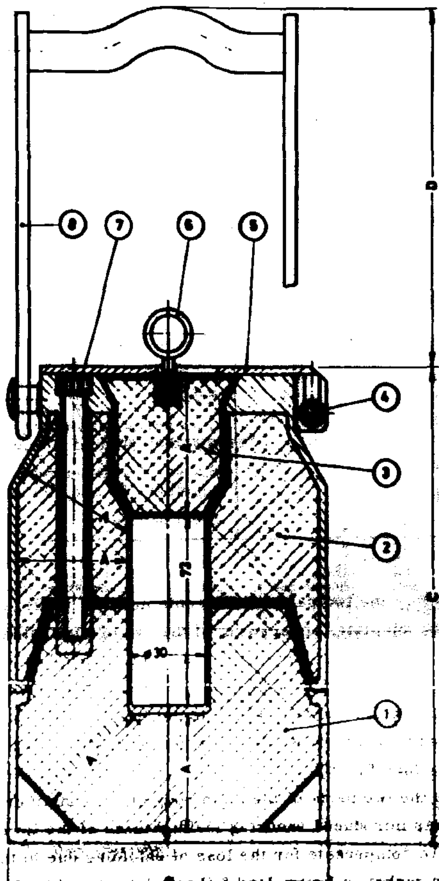
8
7
6
5
4
3
2
1
D
C
⌀30

Table 3

Basic dimensions of the closed-type lead containers

Wall thickness mm	A mm	B mm	C mm	D mm	Description of parts Nos. 1 to 8
45	45	127	185	137	
60	60	157	207	107	
80	80	197	248	200	
100	100	237	288	197	
Part No. 1					Lower part ensheathed in stainless steel
- 2					Upper part ensheathed in stainless steel
- 3					Plug ensheathed in stainless steel
- 4					Two lid-fastening screws
- 5					Steel lid
- 6					Eye lift
- 7					Two screws fastening parts 1 and 2 together (45 and 60 mm)
					Six screws fastening parts 1 and 2 together (80 and 100 mm)
- 8					Steel handle

If necessary the two parts of the container can be disassembled by opening of the top plate, unscrewing of the two or six fastening screws and lifting of the whole upper part of the container. Thus better access can be obtained to the contents located within the cavity of the container.

The construction shown in fig. 5 is not leaktight in itself, but can be easily adapted to make the whole container leaktight. This was done in the following way (see fig. 6).

Between the two parts of the main body of the container a 1.5-mm rubber gasket was introduced ensuring leaktightness of the lower part of the container. To compensate for the loss of shielding due to the introduction of the rubber gasket, a 1-mm lead foil was introduced between the two parts of the lead container (in the upper part of the division space).

The leaktightness of the upper part of the container (through the lead plug) was ensured by introduction of a 2-mm rubber plate and exchange of the steel lid (see part 5 on fig. 5) for a 4-mm steel plate. This plate is in

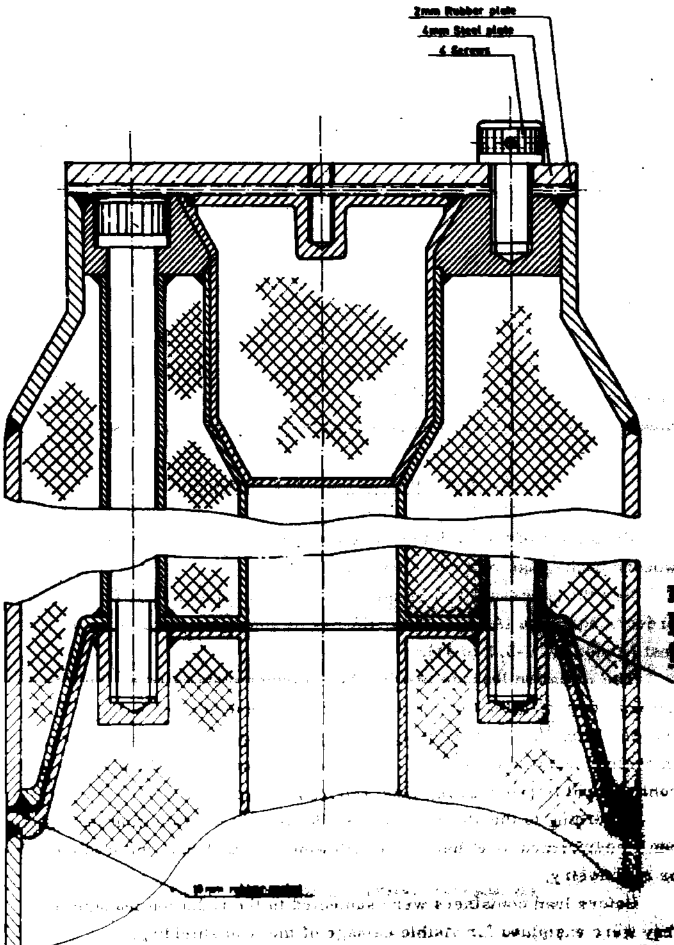

Fig. 6. Clamped-type lead container guide [illegible]

turn pressed down on the rubber plate by four additional screws located at the top of the upper part of the container.

After the above-described modifications the container was tested for leakage in the same way as the tin cans used as containment vessels (see details in 1)). The new construction proved to be leaktight, and the closed lead containers can be used as containment vessels in packagings P8, P9, P10, P11, and P12 (see fig. 1).

5. Radiation Shielding

In the AEC packagings radiation shielding consists of the lead shielding used in the lead containers as well as of the distance shielding provided by the cardboard or wooden boxes.

As mentioned before all lead containers have a cavity of the same dimensions (diameter 30 mm height 73 mm) and a lead shielding of from 5 to 100 mm. The shape of the lead shielding is shown in fig. 7, and the distances from the centre of the packaging to its surface can be seen in fig. 1.

6. Evaluation of Shielding Properties

Evaluation of the radiation-shielding properties of the cardboard and wooden packagings was reported in 2) and 3).

For the assessment of integrity of radiation shielding after the tests prescribed by the IAEA[4)], the IAEA Regulations give a radiation leakage test (Annex IV, I-5.2 of 4)).

The radiation leakage test has been further elaborated by the International Organization for Standardization and is described in para. 3 of the ISO document[5)]. Further details about the radiation leakage test are given in another ISO document[6)]. The method itself was worked out under IAEA contract and is reported in 7), as well as in 8) and 9).

According to the above-mentioned documents the radiation leakage test can be performed by either of the following two methods: autoradiography or radiometry.

Before lead containers were subjected to the radiation leakage test, they were examined for visible damage of the lead shielding.

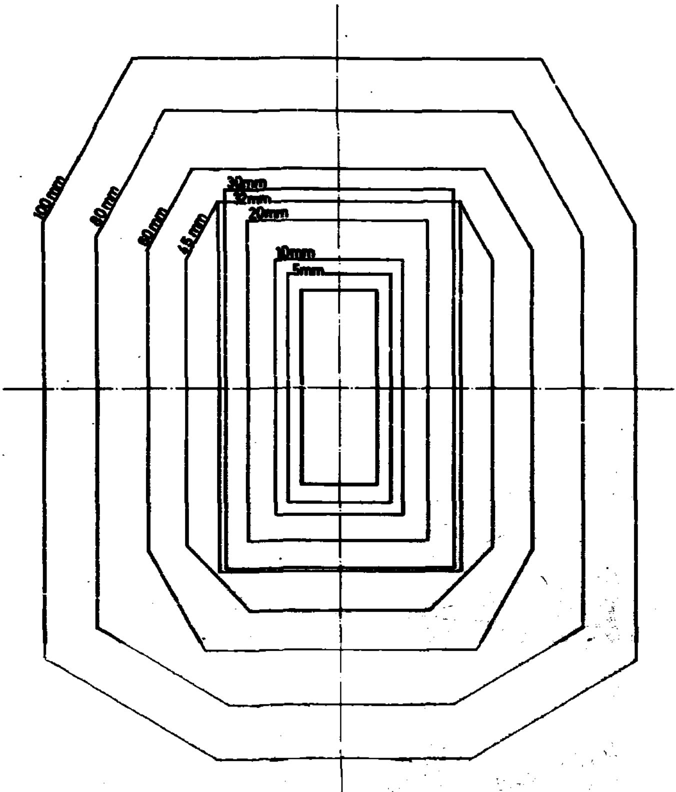

Fig. 7. Lead shielding in different lead containers.

a) Visual Examination

After all the tests performed on the cardboard and the wooden packagings (described in 1), 2), and 3)), the lead containers were examined for visible damage.

This examination gave the following results:

1) Of the tests prescribed by the IAEA[4] only the penetration test caused damage to the lead containers. This was observed for both the open as well as the semi-closed containers. The damage was, however, so small that it may be disregarded. Fig. 8 shows the 10-mm open lead container after the penetration test in the $P3_S$ cardboard packaging. In another case a small indentation in the top part of the semi-closed 30-mm lead container was observed after the penetration test performed on the P5 wooden packaging.

No damage was observed in the closed lead containers, when they were used in the wooden boxes.

2) The 32-mm open lead container used in the P13 cardboard package showed a deformation of the lifting handle after the 1.2-m free-drop test which followed the water spray test (see fig. 9).

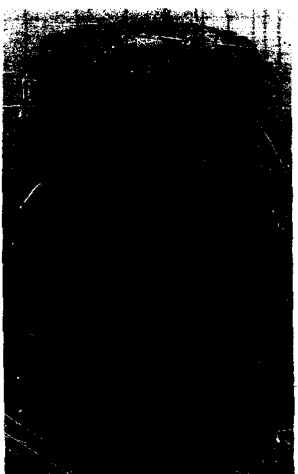

Fig. 8. Open 10-mm lead container after penetration test in $P3_S$ cardboard packaging.

Fig. 9. Deformation of the lifting handle in the 32-mm lead container after the water spray test with impact (1.2 m) in P13 cardboard packaging.

3) The greatest damage was observed after the median accident test, which, however, is not prescribed by the IAEA Regulations[4].

The 5-mm lead containers that were subjected to the median accident test in the PI_S packaging were damaged to such an extent that the glass bottle within the cavity broke (see fig. 10a). This happened when penetration was through the top of the container (fig. 10b shows the internal view of the damaged upper part of the lead container).

The median accident test performed from the side of the containment vessel produced less severe results (glass bottle did not break). However, the lead shielding was damaged to such an extent as to disqualify the container (see figs. 11a and b).

The median accident test did not break the glass bottle in the 10-mm lead containers, but the lead shielding was seriously damaged as shown in figs. 12a and b.

b) Radiation Leakage Test by Autoradiography

For performance of the radiation leakage test by the autoradiographic method it is necessary to calibrate the X-ray films first. This was done in the following way. Kodak-Kodirex X-ray films with lead-intensifying screens (0.15 mm front and 0.25 mm back) were exposed to Ir-192, Cs-137 and Co-60 gamma-radiation. Films were irradiated with doses from 20 to 2000 mR. Calibration was made of eleven films for each lead thickness, corresponding to the wall thickness of the lead containers. Each series of eleven films was simultaneously exposed, and dose modulation was obtained by placing of the films at different distances from the radiation source. The distances were chosen so that the logarithms of the radiation doses reaching the films differed by the same increment. The distances, the radiation doses and their logarithms are given in table 4.

Fig. 10a. Open 5-mm lead container after the median accident test in $P1_S$ cardboard packaging (penetration from top; glass bottle broken).

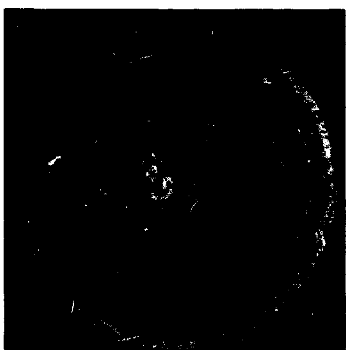

Fig. 10b. Inside view of the upper part of the 5-mm lead container from fig. 10a.

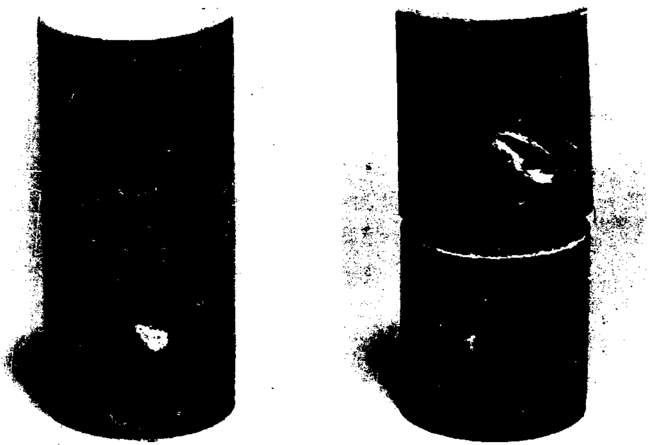

Fig. 11. Open 5-mm lead container after the median accident test (from the side of containment vessel). a) in the $P1_S$ cardboard packaging b) in the $P1_L$ cardboard packaging.

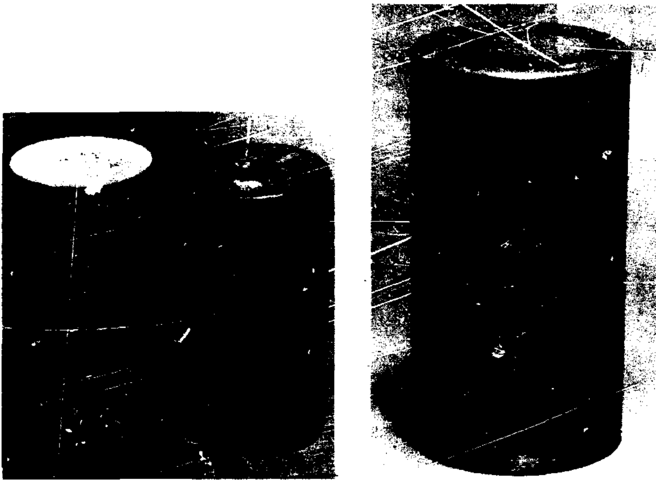

Fig. 12. Open 10-mm lead container after the median accident test. a) in the $P3_S$ cardboard packaging (at left - penetration from the side; at right - penetration from the top). b) in the $P3_L$ cardboard packaging (penetration from the side).

Table 4

Exposure data for film calibration

Film position	FFD[x] cm	Dose mR	$\frac{Dose}{20}$	$\log\left(\frac{Dose}{20}\right)$
1	200	20	1.0	0
2	158	32	1.6	0.2
3	126	50	2.5	0.4
4	100	80	4	0.6
5	80	125	6.25	0.8
6	63.5	200	10	1.0
7	50	320	16	1.2
8	40	500	25	1.4
9	31.6	800	40	1.6
10	25.2	1250	62.5	1.8
11	20	2000	100	2.0

[x] FFD: Focus-Film-Distance

The radiation sources used for calibration were the following:

- Ir-192; 1 x 1 mm; 1 Ci
- Cs-137; 3 x 3 mm; 540 mCi
- Co-60; 4 x 4 mm; 1 and 10 Ci

The Ir-192 and Cs-137 sources were used in a "Pantatron" gamma-radiography machine (R 31 container and C 5 remote control box), and the Co-60 sources were used with the Risö Health Physics Department automatic irradiation and calibration facility[10].

Characteristic Curves of X-ray Films. With the above-mentioned sources Kodak-Kodirex X-ray films with 0.15 + 0.25 mm lead intensifying screens were exposed to gamma-ray doses as shown in table 4. Exposures were made through lead filters of different thicknesses corresponding to the wall thicknesses of the lead containers as shown in table 5.

Table 5

Lead filters used for calibration of X-ray films

Radiation source		Lead filter
Isotope	Activity	mm
Ir-192	1 Ci	0
		5
		10
		20
		30
Cs-137	540 mCi	0
		5
		10
		20
		30
		45
Co-60	1 Ci	0
		5
		10
		20
		30
	10 Ci	45
		60
		80
		100

Exposure times were calculated from the curves given in fig. 13. The curves give the exposures in Ci · h that are necessary to obtain a 1 R dose of gamma-radiation on an X-ray film placed at 1 m focus-film-distance from the radiation source. They were computed from gamma radiation attenuation curves for lead as given e.g. in 11), 12) or 13). For focus-film-distances different from 1 m the exposure $E_{1/1}$ read from curves in fig. 13 should be divided by the distance factor DF, which can be read from the curve given in fig. 13 (at right, below) for different FFD's.

By the above-mentioned procedure samples of X-ray films were irradiated with different gamma-ray sources and lead filters (see table 5), and characteristic curves for X-ray films were computed, giving net film densities (without background and fog density) against radiation dose.

As mentioned before the doses reaching the film were calculated from lead attenuation curves. Besides the actual dose was measured for each exposure at 126-cm FFD with the condenser type dosimeter (Landswerk Roentgen Meter, Mod. L-64, Ser. 112) and a 100 mR ionization chamber.

If necessary, corrections were made of the calculated dose values. Further for each radiation source a single characteristic curve was produced giving the mean values for different lead filtrations. The curves are shown in fig. 14.

Exposure Charts for Lead. To obtain the exposure E necessary to produce the desired density D on an X-ray film at a given FFD, the exposure $E_{1/1}$, read from fig. 13, for the given lead thickness d_{Pb} should be divided by the distance factor DF (see fig. 15) and multiplied by the X-ray film speed factor FS:

$$E = E_{1/1} \frac{FS}{DF} \ (Ci \cdot h) \ . \qquad (1)$$

The X-ray film speed factor FS can be read from the characteristic curves of X-ray films (see fig. 14) as the dose (in R) necessary to produce the desired density D on the X-ray film.

Table 6 gives film speed factors FS read from the curves in fig. 14 for densities D = 1.0, 1.5, 2.0, 2.5, and 3.0.

By insertion of values for FS from table 6 into formula (1) the exposures necessary to produce the desired film densities at 1 m FFD were calculated, and exposure charts were computed for Ir-192 (fig. 16), Cs-137 (fig. 17) and Co-60 (fig. 18).

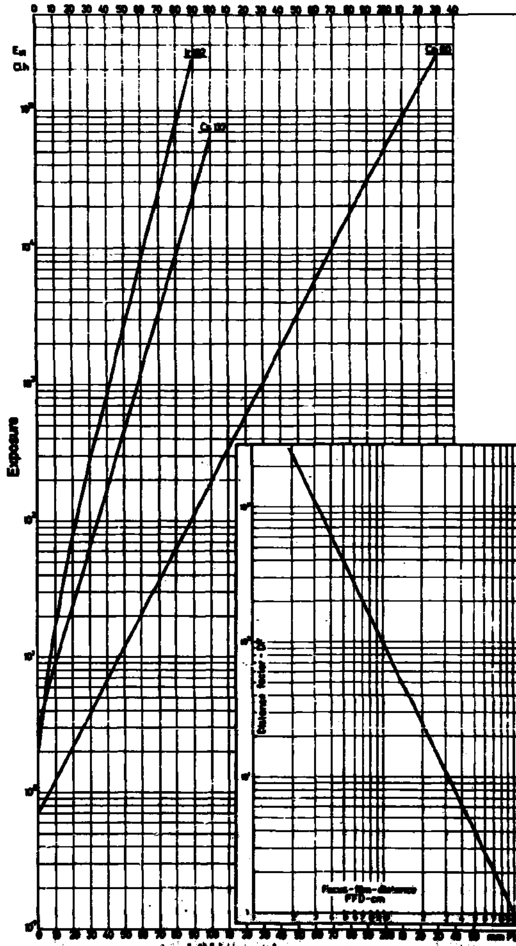

Fig. 13. Universal X-ray film exposure chart (exposure in Ci · h to get 1 R at 1 m FFD).

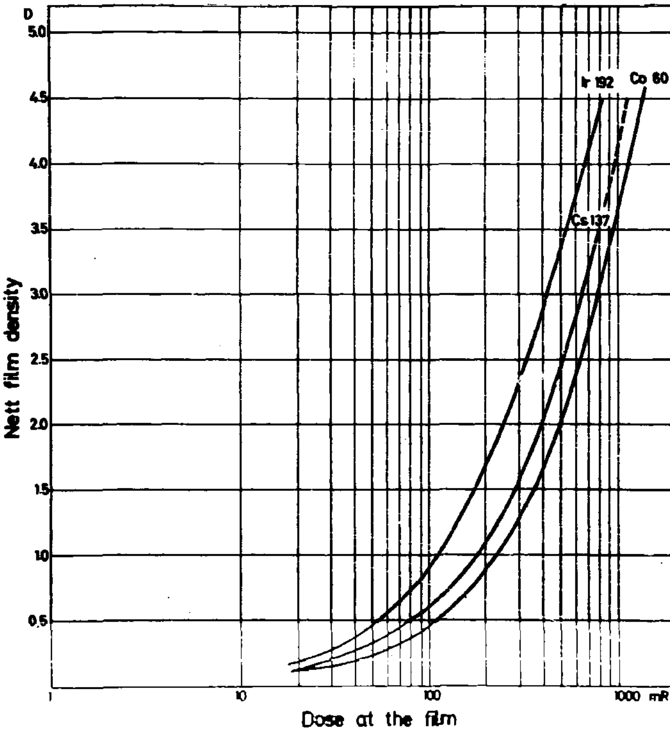

Fig. 14. Characteristic curves for Kodak-Kodirex X-ray films (with 0.15 + 0.25 lead-intensifying screens) exposed through lead filtration to Ir-192, Cs-137 and Co-60 gamma radiation.

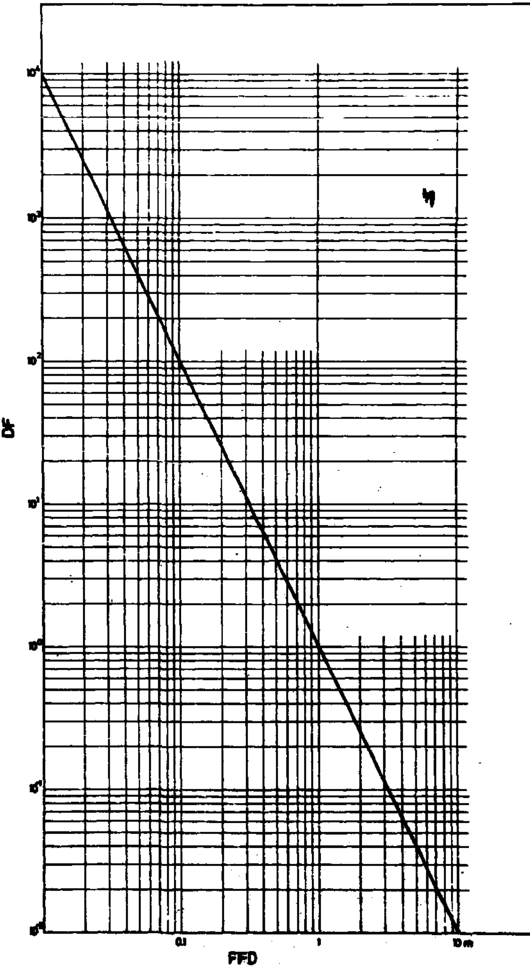

Fig. 15. Distance factor DF for different FFD's.

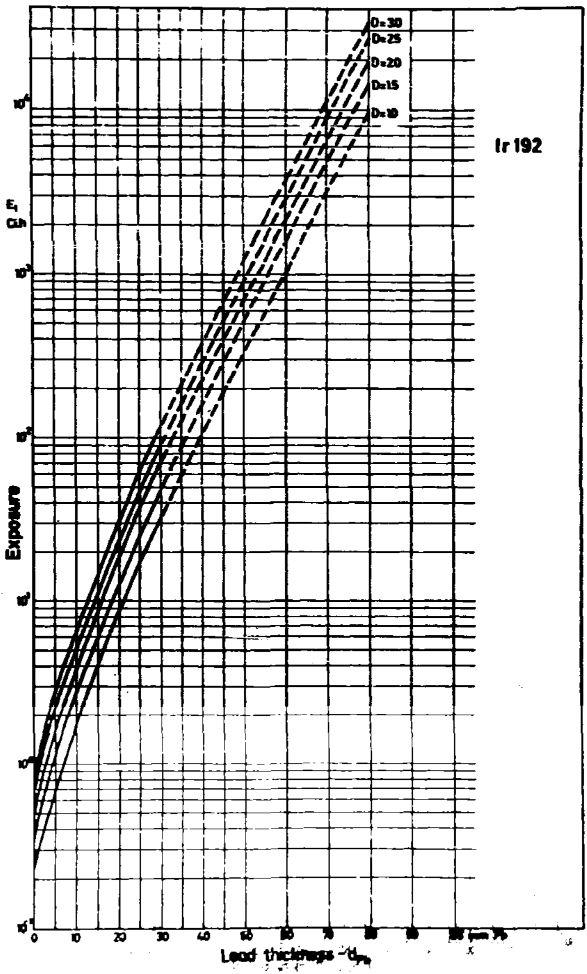

Fig. 16. Exposure chart for Kodak-Kodirex X-ray film (with 0.15 + 0.25 lead-intensifying screens) and Ir-192 (1 m FFD)

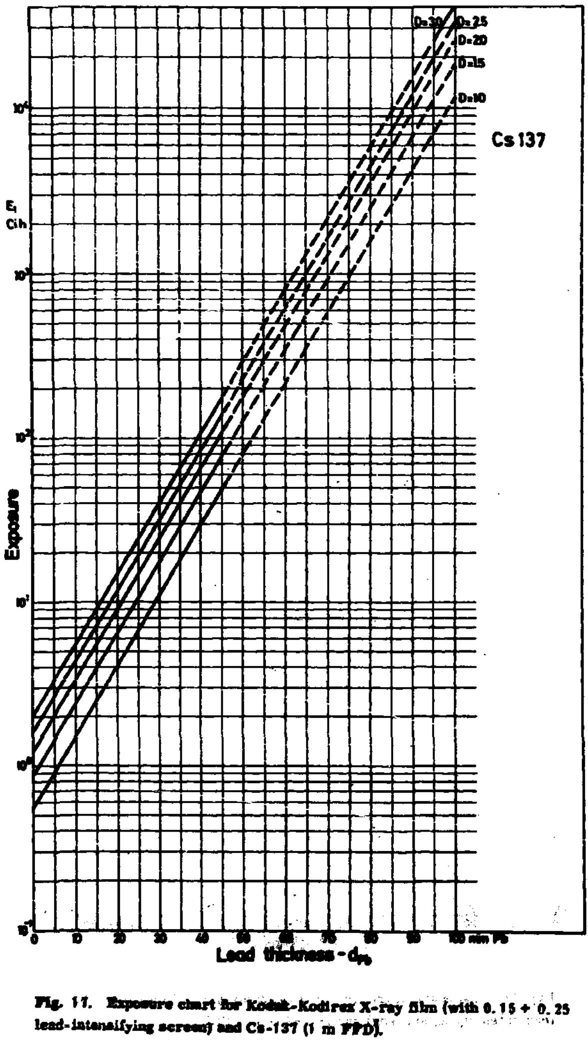

Fig. 11. Exposure chart for Kodak-Kodirex X-ray film (with 0.15 + 0.25 lead-intensifying screen) and Cs-137 (1 m FFD).

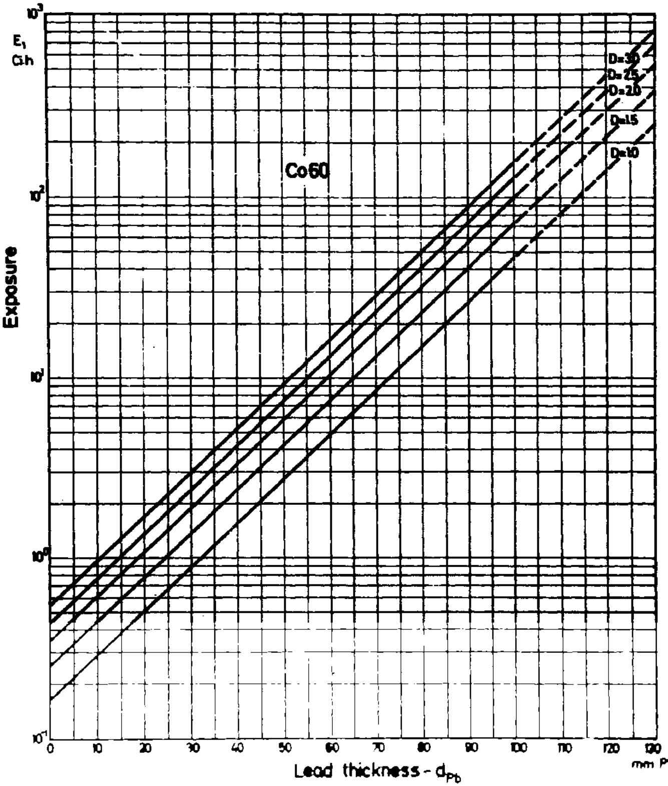

Fig. 18. Exposure chart for Kodak-Kodirex X-ray film (with 0.15 + 0.25 lead-intensifying screen) and Co-60 (1 m FFD).

Table 6

Film speed factors for Kodak-Kodirex X-ray films with 0.15 + 0.25 lead-intensifying screens

Radiation Source	Film speed factor at density D				
	1.0	1.5	2.0	2.5	3.0
Ir-192	0.112	0.175	0.240	0.325	0.420
Cs-137	0.180	0.285	0.390	0.520	0.660
Co-60	0.230	0.360	0.490	0.640	0.790

Autoradiographic examination of lead containers can be performed by the above-mentioned method, and with the exposure charts in figs. 16, 17, and 18.

For lead containers used by the AEC the exposures for Kodak-Kodirex X-ray films can be calculated for the following distance factors.

Table 7

Distance factors for lead containers examined by autoradiography

Lead thickness mm	FFD cm	Distance factor DF
5	2	2500
10	2.5	1600
20	3.5	660
30	4.5	410
45	6.0	[illegible]80
60	7.5	155
80	9.5	105
100	11.5	70

For the autoradiographic examination the radiation source is placed in the cavity of the lead container, and the outside surface of the container is wrapped in X-ray film. For that purpose three films are used: two (in rigid film cassettes) for examination of the top and bottom of the cassette (placed above and beneath the container) and one (in a flexible cassette) for examination of the container walls (wrapped round the container).

For this examination it is essential to use radiation sources with the dimensions of the active part as small as possible, and thus gamma-radiography sources are most suitable. Fig. 19 shows the construction of the AEC radiographic sources, and their dimensions are given in table 8.

Table 8

Dimensions of gamma-radiography sources

Active part		Dimensions in mm						
Diameter mm	Height mm	A	B	C	D	E	F	H
0.5	0.5	23.3	7.0	6.35	1.05	0.55	5.25	5.64
1.0	1.0	23.3	7.0	6.35	1.05	1.05	5.25	5.64
2.0	2.0	23.8	7.5	6.35	2.05	2.05	5.75	5.64
4.0	4.0	24.8	7.5	6.35	4.05	4.05	6.75	5.64

The gamma-radiography sources can be accomodated in the cavity of the lead containers. For that purpose a special source holder was constructed that fits into the cavity of the container, and in which various radiography sources can be inserted (see fig. 20). After insertion of the source the source holder can be closed with a special plug and placed in the container cavity. This can be done by means of a manipulator that can lift the source holder by a folding wire loop provided for that purpose at the top of the perspex source holder.

After exposure of the X-ray films for a length of time necessary to reach the desired film density, the films can be evaluated on a negatoscope, and in the areas where differences of film densities can be observed the densities can be measured on a film densitometer.

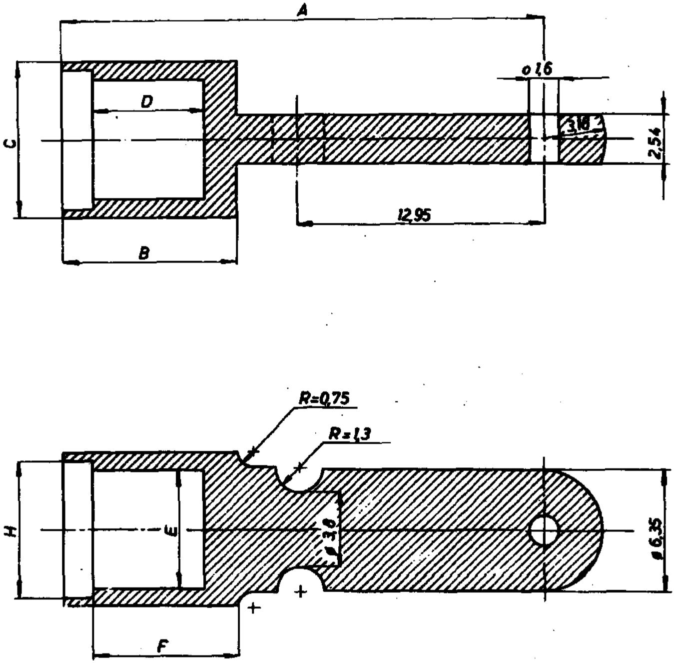

Fig. 19. Gamma-radiography sources.

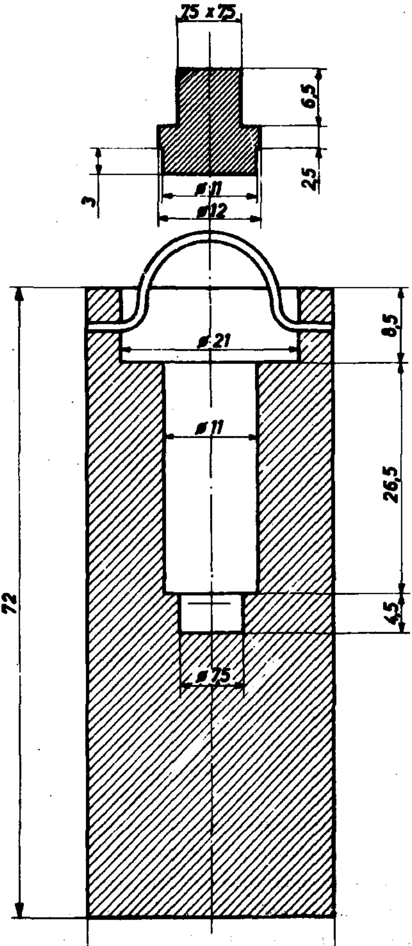

Fig. 20. Source holder.

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Evaluation of Autoradiographic Findings. According to the ISO 85 N 95 document[5)] the interpretation of autoradiographic test results is made in the following way (para 3.3 of 5)): "If when using Ir-192 as radiation reference source, the increase in dose rate is so limited that:

a. it does not exceed 100% when averaged over any 1 cm^2 of surface area, and

b. it does not exceed 20% averaged over any 100 cm^2 of surface area,

then this may be regarded as a practical interpretation, in engineering terms, of no significant loss of shielding efficiency.

Other sources than Ir-192 may be used when more appropriate, but in such a case the percentage increase in dose rate mentioned above shall be so adjusted that the resultant permitted losses of shielding efficiency are not greater than those permitted by the above criteria".

The X-ray film density increase corresponding to the above-mentioned 100% and 20% dose increase can be calculated from the X-ray film characteristic curves, as shown in fig. 14.

This is done in the following way. For Ir-192 used as radiation reference source an X-ray density increase corresponding to 100% and 20% dose increases can be calculated directly from the characteristic curve in fig. 14. For each basic film density (e.g. D_0 = 1.0, 1.5, 2.0, 2.5, and 3.0) the corresponding dose is read from the Ir-192 curve of fig. 14, and this dose is then multiplied by 2.0 (100% dose increase) or by 1.2 (20% dose increase). For the resulting dose the corresponding film density D is read again from the same curve, and then the density increase ΔD is calculated as $\Delta D = D - D_0$. The results of these calculations are shown in fig. 21 a for the 100% dose increase (upper curve) and 20% increase (lower curve).

For radiation sources other than Ir-192 a different procedure must be used. As it is required that the dose-rate increase has to be judged with Ir-192 as radiation reference source, the 100% and 20% dose-rate increase for Ir-192 gamma-radiation must first be translated into actual losses of shielding for different lead thicknesses. This can be done by means of lead attenuation curves as e.g. in 11), 12) or 13) or by means of the universal X-ray film exposure chart in fig. 13.

The results of such calculations are shown in table 9.

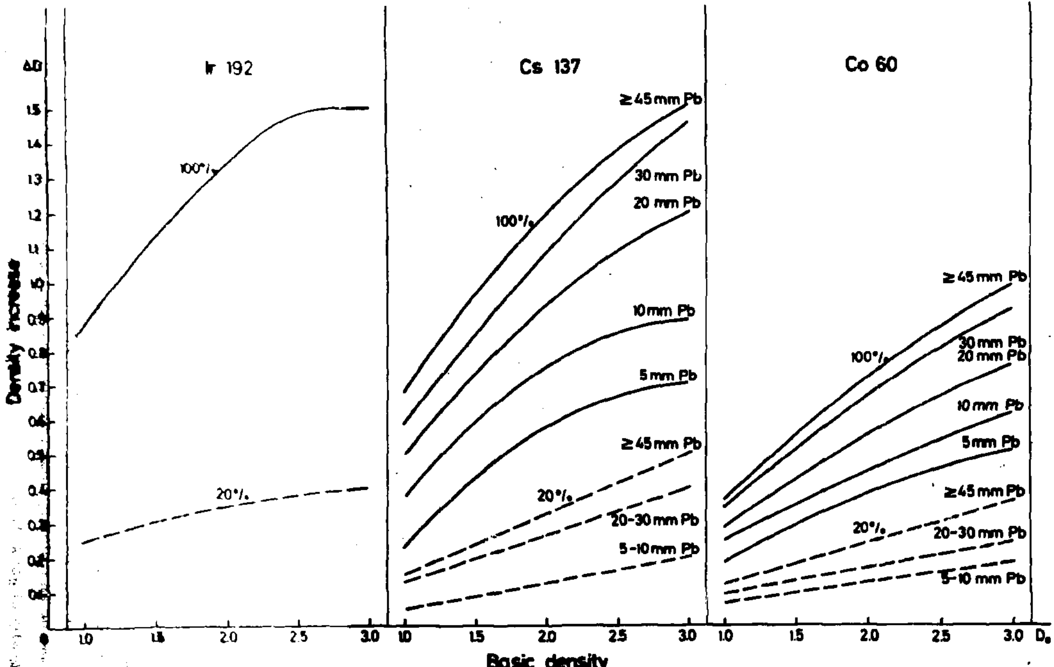

Fig. 21. Film density increase corresponding to 100% and 20% dose increases with Ir-192 as radiation reference source. a) for Ir-192, b) for Cs-138, c) for Co-60.

Table 9

Decrease of thickness of lead shielding that will result in 100% and 20% dose-rate increases for Ir-192 gamma-radiation

Lead thickness mm	Shielding decrease in mm for 100% dose-rate increase	Shielding decrease in mm for 20% dose-rate increase
5	3.2	1.0
10	4.0	1.0
20	5.0	1.5
30	5.5	1.5
45	6.0	2.0
60	6.0	2.0
80	6.0	2.0
100	6.0	2.0

On the basis of these values and the curves for Cs-137 and Co-60 the dose-rate increase was calculated corresponding to identical decreases in lead thickness. For the dose increases the film density increase was in turn read from the characteristic curves of fig. 14, and in this a way the $\Delta D = f(D_0)$ curves could be produced as shown in figs. 21 b and c.

Autoradiographic Examination of Shielding Efficiency. With all the above-mentioned calculations taken into account the following procedure is to be followed for the evaluation of shielding efficiency by the autoradiographic method:

1) For a given wall thickness of the lead container under examination a gamma-radiography source shall be chosen with such an activity as to permit autoradiography within reasonable exposure time.

2) The exposure time can be calculated from one of the exposure charts given in figs. 16, 17 or 18, taking into account the distance factor (table 7) and source activity as well as the desired X-ray film density.

3) For reading of film densities corresponding to a 100% dose rate increase on an ordinary densitometer it is advisable to expose X-ray films to a density of about 1.5.

4) After the exposure time has been determined the radiation source is placed in a suitable source holder (see fig. 20), the container under examination placed on a cassette with X-ray film, wrapped in another cassette and a third cassette is placed on top of the container. For containers with protuding parts (e.g. the AEC 20 and 30 mm containers) an aluminium sheet (about 0.5 mm thick) may be used to accomodate the flexible cassette and to ensure equal distance from the container over the entire circumference.

5) After processing, the X-ray film is examined on a negatoscope, and areas with increased density are measured by means of a film densitometer. Then the density increase in those areas is calculated.

6) Next, the values calculated for density increase are compared with admissible density increase given in fig. 21.

7) If for a surface area not larger than 1 cm^2 this density increase is not greater than shown in fig. 21 for a 100% dose increase, or if for a surface area not larger than 100 cm^2 the density increase is not greater than shown for a 20% dose increase, then the container can be regarded as having adequate shielding efficiency.

c) Radiation Leakage Test by Radiometry

Another possibility for performance of the radiation leakage test is the radiometric method (described in 6), 7), 8) and 9) and approved by the ISO[5)] as well as by the IAEA[4)].

The test procedure consists in placing of a radiation source in the cavity of the lead container under examination. For that purpose the same source holder as used for autoradiography can be used (see fig. 20). The activity of the radiation source shall be chosen in such a way as to ensure adequate accuracy of the dose-rate measurement with the radiation detector in use. As radiation detector and dose-rate measuring instrument a scintillation counter may be used. The scintillation crystal is to be housed in a collimator with a well-defined geometry. This scintillation probe (scintillator + collimator) is then affixed to a rotating arm of a rotating turntable, on which the container under examination is placed (see e.g. fig. 9 in 6), fig. 47[7)] or fig. 4[8)]). The container should be placed so that the axis of rotation of the turntable and the axis of rotation of the scintillation probe will intersect at the point in which the radiation source is located in the cavity of the container, and the radiometric examination may then be started by scanning the whole surface of the container with the scintillation counter (e.g. by rotating of the turntable and moving of the scintillation probe through a constant angle after each revolution). The dose-rate measurements of the scintillation counter are registered on chart paper.

Calibration of Equipment. Prior to the examination of lead containers a calibration of the scintillation counter is necessary. Without it neither choice of source activity nor interpretation of test results is possible.

The calibration consists in establishment of a relationship between the count rate of the scintillation counter with collimator at a fixed geometry (distance from scintillator to radiation source) for gamma-radiation sources to be used during radiometric examination (Ir-192 and Cs-137 or Co-60 if necessary). Further calibration is necessary for each radiation source to be used during the radiation leakage test to determine the count rate increase corresponding to a 100% and 20% dose-rate increase with Ir-192 as radiation reference source. This calibration can be performed with lead filters of thicknesses corresponding to the nominal wall thickness of the containers under examination and then with gradually decreasing lead filter thickness to reach the 20% and 100% dose rate increase.

Evaluation of radiometric findings is made by comparison of the registered count rates obtained during the scanning of the containers with the scintillation probe with the count rate increase obtained during calibration for the 100% and 20% dose rate increase. Here a similar procedure may be used as for the evaluation of autoradiographic findings (see para b) above).

Radiometric equipment necessary to perform the radiation leakage test consists of two parts, one of them mechanical and one electronic. The mechanical part of the equipment is composed of a turntable (see fig. 22) on which the container under examination is rotated and to which a rotating arm with the scintillation probe is attached. As can be seen in fig. 22 the upper part of the turntable consists of a round pertinax plate (low gamma-ray absorption coefficient) on which the lead container is placed. To keep the container in a central position on the turntable four pertinax plugs are used. They can be placed in different holes in the top plate to accomodate containers of different diameters.

As mentioned before the container under examination should be placed on the turntable in such a way that the axis of rotation of the turntable and the container will intersect with the axis of rotation of the moving arm with the scintillation probe at the point in which the radiation source is located in the container.

The source holder brings the radiation source into a central position in the container. The four pertinax plugs centre the container in such a way that the radiation source is on the rotation axis of the turntable.

Fig. 22. Turntable with scintillation probe.

For the radiation source to be brought to the point of intersection of the above-mentioned two rotation axes the upper platform of the rotation-table can be moved up and down as it is fastened to a cylindrical steel tube with internal thread.

Fig. 22 shows the scintillation probe in different positions. In all those positions the central beam, which will reach the scintillation detector through the conical collimator, passes through the point of intersection of the two rotation axes, at which the radiation source is located.

The turntable is driven by an electric motor (see lower left in fig. 22) at a constant speed of 0.8 r.p.m.

Fig. 23 gives a close view of the rotation mechanism of the moving arm at which the scintillation probe is accomodated. By turning of the handle of this mechanism the arm can be brought from its vertical position both ways down, and the angle at which the probe aims at the radiation source can be read at a scale.

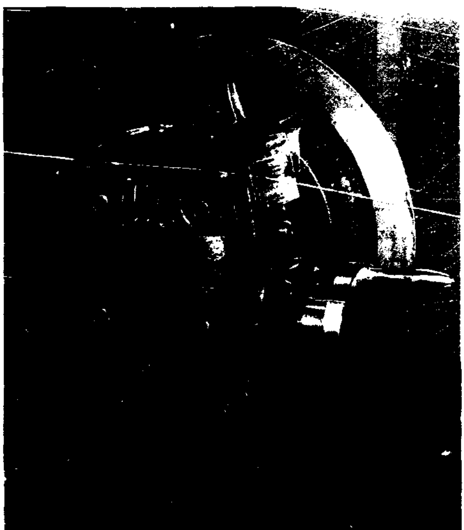

Fig. 23. Rotation mechanism of the moving arm.

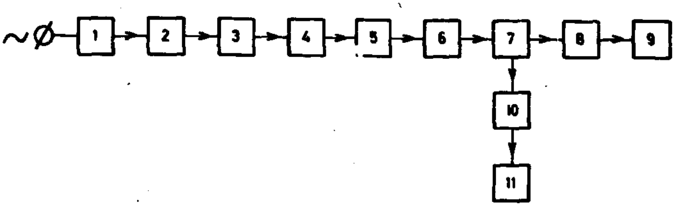

Fig. 24. Block diagram of the electronic equipment.

The electronic part of the equipment consists of the following elements (see block diagram in fig. 24):

1) Main switch and total-time timer.
2) Low-voltage supply.
3) High-voltage supply (Nuclear Enterprises NE 4604).
4) Scintillator (1" or 2") with photomultiplier.
5) Preamplifier (in the scintillation probe).
6) Amplifier (Nuclear Enterprises NE 4603).
7) Single-channel analyser (Risö P 87 a).
8) Ratemeter (Nuclear Enterprises NE 4607).
9) Recorder (Risö P 146 a).
10) Timer (Risö P 183 a).
11) Scaler (Risö P 174 a).

The elements can be used in the following two ways:

- The count rate going out of the single-channel analyser (7) can be read on the measuring instrument of the rate meter (8) and recorded on chart paper by the recorder (9), or

the count rate can be calculated from the readings of the timer (10) and scaler (11) connected to the single-channel analyser (7).

The first technique is used for examination of the lead containers for radiation leakage, where the results of the measurements are recorded on chart paper, and the other technique can be used for calibration purposes, where more accurate readings of the count rates are necessary.

A general view of the whole measuring assembly is given in fig. 25. Here the electronic part of the measuring apparatus is shown at right in the picture. It is accomodated in a vertical panel and the above-mentioned elements can be seen in the following sequence:

At the bottom from the left - high-voltage supply (3), amplifier (6), rate meter (8); above these - recorder (9); above recorder-timer (10) and above that - scaler (11); next - low-voltage supply (2) and main seitch and timer (1); at the top of the panel - single-channel analyser (7).

d) Assessment of Radiation Shielding

Each lead container used in the packaging of radioactive material has its nominal value of lead shielding. According to this nominal thickness the activity of the radioactive material that may be transported in the packaging is calculated.

The radiation leakage test can serve two purposes:

1) It can be ascertained that the radiation shielding of the container is not inferior to the nominal value over the entire surface of the container.

2) It can be ascertained that the radiation shielding of the container has not deteriorated after the packaging has passed all the tests prescribed by regulations and standards.

For the above-mentioned purpose to be reached the lead containers must be tested twice: Once before they are submitted to the other environmental tests to check the shielding properties of the container and determine its minimum shield thickness (and compare it with the nominal value), and once more after the environmental test to check that the shielding properties have not changed as a result of the above testing and to ascertain that any changes of the shielding properties lie within admissible values.

7. Conclusions

From the investigation performed the following conclusions can be drawn:

1) The series of open-type containers, including till now only the 5 and 10-mm containers, can be extended to 20 and 30 mm.

2) The new open-type, 20-mm lead container can be used in tin cans as containment vessels.

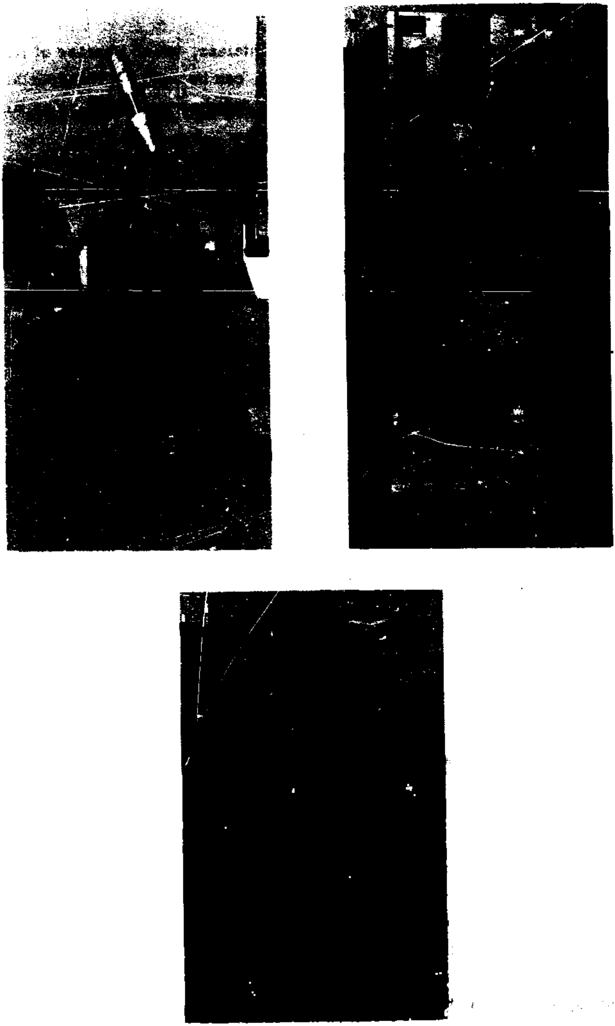

Fig. 25. General view of the assembly for the radiation leakage test by the radiometric method.

3) The new open-type, 30-mm lead container, which because of its height cannot be accomodated in the tin can, can be used for transportation of encapsulated, sealed sources, where the source capsule can be regarded as the containment vessel.

4) The use of the present 20- and 30-mm semi-closed type lead containers shall be discontinued where a containment vessel is necessary. They can, however, be used for the transportation of encapsulated, sealed sources (see 3 above).

5) A new type of the 30-mm lead container is necessary. This should be a closed, leaktight container. A construction similar to that shown in fig. 6, which is used for making the present, closed-type containers leaktight, could be used. However, it will be more economical to make a new, simpler design for the 30-mm leaktight container.

6) The present closed-type lead containers can be used in future for transportation also of liquids if their construction is made leaktight, as shown in fig. 6.

7) In all the closed-type, leaktight lead containers, to be used for transportation of liquids and in which the container itself is regarded as a containment vessel, an absorbing material within the cavity of the container is necessary. This absorbing material must be able to absorb twice the volume of the liquid contents (see para C. 2. 2. 2 of 4)). For that purpose spongy, absorbing material such as "Spontex", "Pontex" or "Wetex" may be used.

8) It is necessary to check the shielding properties of all types of lead containers presently in use to see whether the minimum shielding of each container type corresponds to the nominal value. For that purpose one of the radiation leakage test methods described in this report can be used.

9) The radiation leakage test shall be also applied after the environmental tests performed on different types of packagings. The actual testing could be limited to only those cases in which the visual examination of the packaging and lead container after other forms of testing may lead to the conclusion that the shielding properties of the lead container have been diminished, and the shielding properties of the lead container must have been checked prior to the environmental tests. However, contents leakage testing is superfluous if the visual examination reveals damages to the lead shielding, which will obviously disqualify the container (as e. g. shown in fig. 10).

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